AMERICAN Affairs

May 20, 2018

The American Way of Innovation and Its Deficiencies

by David Adler

Apple, Alphabet (the parent company of Google), Microsoft, Amazon, and Facebook are the world's largest companies by market capitalization. The United States is also, by many measures, the leader in university research in basic science. From this perspective, American innovation seems alive and well.

But it's a different story when it comes to actually making things. Apple, as is well known, manufactures its products abroad. The same is largely true for other U.S. corporate giants, such as Amazon. In fact, with the supplier base and knowledge required for manufacturing centered in Asia, the United States no longer has the technological prowess to manufacture many high-tech devices domestically. When it comes to applied research and downstream "process innovation," America lags behind its competitors.

The reasons for this decline are complex. It is partly ideological: for a long time the consensus belief in economics was that advanced countries should specialize in advanced R&D while outsourcing manufacturing to others. Financial short-termism has played a key role too, as has the way free trade with China has played out in practice.

But some of the failings are technical and institutional. Corporate research labs that once developed and commercialized breakthrough technologies have been eliminated. And critically, the United States, unlike Germany or Japan or South Korea, lacks key institutions focused on applied research and innovation. In other countries, such organizations help translate new ideas in science and technology into practical applications in manufacturing.

The United States needs to create a new set of institutions to overcome America's deficiencies in applied research and innovation, particularly when it comes to manufacturing. Such applied research is critical in translating scientific breakthroughs into an increase in middle-class American employment. Restoring this missing link in applied innovation is a necessary step toward restoring the shared prosperity of America's past—precisely what has been lost in the present.

The Deindustrialization of the United States

U.S. manufacturing employment has fallen 30 percent since 2000. Deindustrialization, which in the 1980s was centered in the heavy industry sectors of the Northeast and Upper Midwest, moved to the Sunbelt after 2000. As U.S. factories closed, the locus of manufacturing moved to Asia.

U.S. manufacturing currently stands at about 12 percent of GDP, compared to 18 percent in Switzerland and 22 percent in Germany. Wage differentials do not explain this disparity: U.S. manufacturing workers actually make less than their counterparts in these countries: $35 per hour in the United States compared to $47 per hour in Germany and $60 per hour in Switzerland.[1] (These numbers also show that manufacturing employment is a well-paid activity compared to minimum-wage service jobs.)

The conventional explanation for the decline in U.S. manufacturing employment is not that America has lost its way in applied research and process innovation. Instead, it's the opposite: America's factories are just too good. AI and automation have led to a shedding of marginal, low-value jobs, while output remains strong. Adam Davidson, writing about "Making It in America" in the *Atlantic*, perfectly encapsulates this conventional wisdom:

> In the past decade alone, output from American factories, adjusted for inflation, has risen by a third. . . . The still-unfolding story of manufacturing's transformation is, in many respects, that of our economic age. It's a story with much good news for the nation as a whole . . . [as] mills were able to replace their workers with a new generation of nearly autonomous, computer-run machines.[2]

Yet a more compelling, though less upbeat, explanation of what is happening in U.S. manufacturing is that the output statistics are misleading—if not entirely wrong. Virtually all of the alleged expansion in U.S. manufacturing output has taken place in one sector: computers and electronics, with other sectors contracting. The growth in this sector, however, is in part a function of the way government statistical agencies calculate output: improvements in computer power show up as increases in computers produced. The reported increase in physical computers produced is therefore illusory. Once this statistical approach has been adjusted, overall U.S. manufacturing output actually fell after 2000, along with employment.[3]

The story of the supposed transformation of American manufacturing also cannot explain why manufacturing makes up such a low percentage of GDP in the United States compared to Switzerland or Germany, to say nothing of Japan, Korea, or China. One soothing refrain is that what's left of American manufacturing is still the best in the world. According to this argument, the United States has retained high-value activities while outsourcing low-value activities to other countries. If this were true, however, then one would expect American industry to be making the high-value machines used in foreign factories. In reality, the United States barely has a machine tools industry to speak of. It is about the size of Italy's. America's largest import from China is electrical machinery, followed by general machinery. Its largest exports to China: grains, seeds, and fruit.

The idea that America is building the factories of the future is further belied by the actual use of robots in manufacturing. The United States lags behind global leader Korea in terms of robots per person by two-thirds. The intensity of robot usage in the United States is actually behind that of the Czech Republic and Slovenia.[4]

In fact, labor productivity in many U.S. manufacturing sectors is declining. Of the fifty-one durable manufacturing industry sectors surveyed by the Bureau of Labor Statistics, thirty-four experienced productivity decreases in 2017, led by the transportation equipment industry's 11.5 percent decline. In nondurable manufacturing, productivity fell in twenty of thirty-five industry sectors.[5]

Not only is America shedding low-value, blue-collar manufacturing jobs, it is shedding white-collar manufacturing jobs too. Remarkable—yet rarely remarked-upon—statistics show the difference between America and other advanced countries when it comes to jobs in manufacturing. The economists Bart Los, Marcel Timmer, and Gaaitzen de Vries found that low- and medium-skilled manufacturing jobs declined across Western countries in the manufacturing global value chain. This is where the similarity between the United States and other advanced countries ends, however. The authors write: "whereas in Europe and Japan, high-skilled job opportunities have increased, they have declined in the United States since 1995."[6]

These statistics present a very different picture from the conventional narrative in which an essentially healthy manufacturing industry is automating blue-collar employment away. Instead, the reality is one of an eroding industry, with both low- and high-paying manufacturing jobs leaving the United States. The statistics don't explain why these trends are taking place—both trade and decline in competitiveness are complementary explanations—only that they are real and alarming. But they do represent another indication that the United States is falling behind the frontier of applied research and innovation in manufacturing—far behind.

Two Types of Innovation

"Innovation," beyond its warm and fuzzy overtones, can mean many different things. Analysts often distinguish between advanced or upstream R&D and applied R&D. Political economists Dan Breznitz and Peter Cowhey have sharpened this analytical framework. They differentiate "*novel-product innovation*," in which "the creator conjures an entirely new technology or product," from "*incremental and process innovation,*" which represents "improvements in how goods or services are designed, produced, distributed, and serviced."[7] Breznitz and Cowhey note that process innovation has the larger impact on economic growth, particularly when it comes to growth in jobs.

Historically, the United States excelled in both types of innovation, but this is no longer the case. While America remains a global leader in upstream R&D, applied research and its supporting corporate ecosystem have withered if not vanished, or have moved to sites of manufacturing outside the United States. Well-paying jobs in U.S. manufacturing have also vanished as a result. This loss of applied innovation could be the overlooked cause of the mysterious stagnation in American productivity growth.

The Disappearance of the Corporate Innovation System

Corporate laboratories were once a critical part of the American innovation ecosystem. Maintained by large, vertically integrated corporations, these labs created scientific breakthroughs and also found ways to apply and commercialize innovations. Their absence haunts current attempts to revive U.S. manufacturing.

Henry Kressel, former director of RCA Labs, offered a definitive history of corporate research laboratories in the Winter 2017 issue of *American Affairs*.[8] He notes that RCA Labs invented the core technologies used in color television (for example) as well as the necessary manufacturing methods. RCA Labs can take credit for numerous other scientific breakthroughs, such as liquid crystal flat-panel displays, high-power silicon transistors, and semiconductor lasers. Kressel himself developed an efficient manufacturing technology for these lasers, enabling them to go from a "laboratory curiosity" to a commercially useful product in just two years.

But starting in the 1970s and '80s, American corporations stopped pursuing these long-term research projects. Kressel poignantly describes the demise of lab after lab. These losses include Westinghouse Research Labs, which created the foundational technology for flat-panel displays; Hughes Research Laboratories; the Xerox Palo Alto Research Center; and his own RCA Labs, which was spun off. Kressel writes of this loss: "There is a great deal of innovative work in the United States . . . but where are the institutions that will foster the next generation of breakthroughs in process technologies, new materials, or infrastructure technologies?"[9]

There is a financial side to this story—indeed the whole story behind the demise of corporate research labs and the decline of process innovation in general. As financial markets began playing a larger role in the U.S. and global economy, short-term market pressures and the search for "shareholder value" pushed companies to outsource manufacturing and to cut corporate R&D, regardless of the long-term consequences.

Activist investors have had an outsized role in killing off the remaining corporate research labs. One of the main activist strategies is to demand the breakup of large, vertically integrated corporations. Because conglomerates are out of style in the stock market, their individual business units are typically worth more as separate entities than as part of a whole. Breaking apart large corporations "unlocks value" for the shareholder when financial markets value the shattered remnants of the corporation at higher multiples than the original conglomerate. Central research labs are almost always a casualty, eliminated as a result of the breakup of the corporate parent.

Indeed, activist investors seem to have a special enmity for central corporate labs. The handful of remaining research labs in the United States, such as the lab at DuPont, have come under fire from activist investors. Following the activist-engineered merger of Dow and DuPont (and vast layoffs at DuPont's central research and development organization), Trian Fund Management's Nelson Peltz turned his attention to Procter & Gamble. Here again, the activist sought a "lean holding company," meaning cutbacks in R&D. According to Procter & Gamble's CEO, Peltz said that corporate research should be viewed as no more than "a hobby."[10] Harvard Business School professor Dan Lorsch said, "If it was up to the activists there would be no [central research labs]."[11]

It is unfair to blame activist investors alone for the reduction in long-term corporate R&D, however. Corporations often follow the activist playbook of their own accord—spinning off noncore business units, outsourcing manufacturing and most of the value chain supporting it, as well as cutting both advanced and applied R&D. Stock market pressures (which often affect executive compensation) are driving this strategy.

Stock markets may undervalue central labs because they produce positive "externalities"—benefits that accrue to the country or economy as a whole rather than just to the company itself. The share price doesn't reflect this common good. Or maybe stock markets are excessively short-term and don't value the patient research undertaken by the labs and the long-term benefits they provide.

Regardless, as large, vertically integrated corporations and conglomerates have been broken up and their central research labs eliminated, more and more of their formerly internal processes have been taken over by external suppliers. But outsourcing production activities to the supply chain has been devastating to manufacturing innovation. Suppliers lack the resources to pick up the slack in research formerly conducted by central research labs. Small and medium-sized manufacturing

suppliers typically undertake no formal research, nor do they have the resources to take advantage of university research, much less to find ways to commercialize and apply it.[12] Further, the U.S. corporate approach has been to squeeze suppliers on the basis of cost, rather than working collaboratively to create new, innovative manufacturing processes. The functions of the central research labs have not been recreated in this new, disintegrated system.

Because the dominant financial market attitude treats corporate R&D as frivolous, corporations are no longer investing in applied research on any scale. Is it really surprising, then, that U.S. business sector labor productivity growth for the last quarter of 2017 was 0.0 percent?[13]

University Basic Research and Its Limitations

The United States has a second source of innovation, and that is government-funded basic research, mostly conducted at universities and often funded through DARPA (Defense Advanced Research Projects Agency). Here, the United States has been more successful. Basic research has been the cornerstone of America's ability to achieve scientific advances that expand the frontier of knowledge, build America's defense capacities, launch new industries, and lead to the creation of entirely new fields.

But there are drawbacks to relying upon this system as the sole source of innovation: it largely excludes the late-stage, applied research needed for the mass deployment of new technology. Although universities may commercialize some of their research through licenses, they can play only a limited role, or more likely no role at all, when it comes to production.

Universities and defense agencies are not a perfect substitute for the vanished corporate system, which combined both advanced and applied research. Universities may create new ideas and technologies, but someone else has to apply those ideas and manufacture the products—and that increasingly takes place abroad. And this portends dire consequences for American jobs and the future dynamism of the U.S. economy.

Economic geographers Jennifer Clark and the late Susan Christopherson found that commercial spin-offs of technological innovations stemming from universities were unlikely to lead to large scale local job creation, at least without a skilled local labor force or venture capital system. Only a handful of U.S. regions, such as the San Francisco Bay Area, have the capabilities to absorb university innovations and build sizable industries around them.

Christopherson and Clark write that the "research on the commercialization of patents produced in universities shows that while universities in the periphery may be producing innovations, production is likely to migrate to the coastal centers." They conclude, "If we examine the potential

economic contributions of the university in regional economic development . . . we see that universities can play only a limited role."[14]

Entrepreneurs who commercialize university (and government-funded) research to create new products can profit handsomely. But the bulk of the jobs, both blue collar and middle class, go to where the product is manufactured, which might be in China. All that is left in the United States, aside from the financial and entrepreneurial overclass, is a servant class of private chefs and personal trainers; the middle-class jobs are located elsewhere.

The resulting inequality that stems from this winner-take-all approach to innovation is not politically sustainable. And since consumer spending accounts for the vast majority of U.S. economic activity, this lack of middle-class job growth is not economically sustainable either.

The Kindle as a Case Study: Loss of Production Knowledge Impacts Advanced Innovation

A case study of Amazon's Kindle illustrates these problems. At present, the United States lacks the technical ability to manufacture the Kindle domestically, despite the fact that most of the core innovations behind the Kindle, such as electronic ink and LCD flat-panel displays, were invented in the United States. Flat-panel technology, for instance, was first proposed at GE and later developed at Westinghouse, but almost all manufacturing of LCD products has now moved to Asia.

Harvard Business School professor Willy Shih has found that only Asian companies currently have the capabilities to make the advanced glass technology used in the Kindle. His conclusion is stark: "the Kindle can't be manufactured in the U.S."[15]

One might argue that this loss of production capability doesn't matter. The United States, and of course Amazon, still capture some value from the production of the Kindle, even if the bulk of the components are made in Asia. In addition to concerns related to job losses or the trade deficit, however, Shih writes that "a more substantive cause for concern is when innovations can't be manufactured in the U.S., the locus of innovation in that area frequently shifts to the countries that can manufacture them."

In other words, because the production of many goods no longer occurs in the United States, America is losing out on future new products and entire industries stemming from discoveries associated with manufacturing. Shih adds, "sometimes when you let your capabilities get away, you give up not only one industry but all its progeny." Ignoring downstream innovation and manufacturing has upstream consequences: America's lead in advanced in R&D has been eroded by its neglect of applied R&D.

A Solution: Innovation Intermediaries

American policymakers and economists seem at a loss to explain, much less stem, deindustrialization. "Education, education, education!" is the commonly offered solution, but it is a vague one, and shopworn too. After all, the collapse in American manufacturing during the 1980s, '90s, and 2000s did not coincide with a decline in educational levels. In fact, the opposite occurred.

Actual, concrete policy solutions are thin on the ground. The typical set of policy choices is tightly focused on tax. Tax cuts are too often seen as the cure-all for whatever is ailing America, regardless of the cause. A more regional approach is to use tax incentives to lure manufacturers, but this only leads to a zero-sum race to the bottom.

And none of these alternatives represents a plausible solution if the American weakness in manufacturing is related to institutional deficiencies in applied research and innovation (as well as trade and financial short-termism). Rather, this institutional failing calls for an institutional remedy: an innovation intermediary.

An "innovation intermediary" is an institution that brings together academia, industry, and the government to foster applied research. Its goal is to translate advanced R&D, developed in universities or government labs, into actual processes that can be used in factories. These institutions could also help to improve workers' skills in using new technology, and they could share technological advances with small and medium-sized manufacturing suppliers that do no research at all. Ultimately, these institutions could overcome the key deficiency in the U.S. innovation system: the lack of applied R&D.

Although an innovation intermediary sounds like a theoretical construct, these organizations actually form a core part of other nations' manufacturing ecosystems. For instance, Germany has Fraunhofer Institutes, which are application-oriented research organizations. They are independent from business and government but are funded by both. Fraunhofers are critical for translating basic research into commercial products. They adapt advanced R&D into applied processes that can be used in manufacturing. They are therefore integral to the German model of innovation, "which applies science, technology, and engineering to drive incremental but constant improvements in processes and technologies."[16] Similar institutions are found in other industrialized countries, such as the Industrial Technology Research Institute (ITRI) in Taiwan or the Public Industrial Technology Institutes (Kohsetsushi) of Japan.

Innovation intermediaries do exist in the United States as well, mostly on a pilot basis. The Manufacturing Extension Partnership (MEP), which has its origins in the Clinton administration, targets smaller to medium-sized enterprises, offering advice about how to deploy technology. More

recently, Manufacturing USA, which was established during the Obama administration, has created national institutes focused on developing commercially applicable new technologies in 3-d printing, photonics, and lightweight materials manufacturing. And there are a handful of German Fraunhofers undertaking contract research that operate in the United States.

But the scale and imprint of these U.S. institutions is not comparable to what exists in other countries. In the first place, the American institutions' budgets are tiny: MEP's budget in 2009 was $110 million. The German Fraunhofers' annual budget, by contrast, is €2.3 billion, for a country much smaller than the United States. Furthermore, continued federal funding for U.S. innovation intermediaries is uncertain, to say the least. Federal funding for Manufacturing USA is designed to sunset, and MEP's funding was nearly cut altogether in President Trump's initial budget proposal. The United States will likely have to find funding sources outside the federal government to support late-stage, applied research.

Meanwhile, Germany has announced "Industrie 4.0," a national initiative designed for smart factories and the manufacturing of tomorrow. This is merely one of ten similar German high-tech manufacturing initiatives. Industrie 4.0 envisions a new industrial revolution, building on big data as well the "Internet of Things." It aims to integrate small to medium-sized enterprises into the world of digital manufacturing. Here too, much of the underlying digital technologies, such as the platforms used for the Internet of Things, was developed in America, but the actual manufacturing will take place in Germany. Industrie 4.0 will tap many sources of funding, including up to $80 billion in innovation research from the EU.

Can anyone imagine the United States launching something similar today?

Political Barriers to Creating Innovation Intermediaries

Everyone claims to love the idea of innovation. Creating new institutions to restore applied research and, with it, manufacturing in America should be a bipartisan project. In reality, however, the efforts necessary to accomplish these goals are out of step with the ideological commitments of both parties.

The Democratic Party should be a natural advocate for such a mission. The Democrats were traditionally the party of the industrial working class and represented the interests of the "the workingman." But today the phrase "workingman" is more likely to be considered a microaggression by party leaders.

Instead, the main ideological thrust of the current Democratic Party is identity politics. The theory of "intersectionality," which examines intersecting structures of oppression, underpins this approach. This total politicization of everyday life along tightly prescribed lines, however, has

nothing to say about the causes of the decline in manufacturing innovation and its effects on U.S. workers. And that's because intersectionality has no real intersection with economics at all.

Intersectional theorists do pay lip service to the importance of class, and some mention of it is usually de rigueur in any discussion. Yet even when intersectional theorists acknowledge that deindustrialization has occurred, they are typically more interested in its disparate impacts, rather than in how to reverse it. Structural economic decline is simply not a galvanizing issue for student protest groups. This sidelining of economic and class concerns can be seen in the way tech and finance billionaires, once they embrace intersectional language and ideology, are embraced by "social justice" movements.

Edmund Phelps, a Nobel laureate in economics, characterized the rhetoric of the Democratic Party this way:

> When Hillary Clinton gave her first campaign speech, she spoke only of social justice for marginalized groups. She focused on groups she judged had no interest in the economy. There was no sense that the nation's economy had largely lost the sustained growth it had been generating.[17]

Aside from offering lip service to redistributive policies, Democrats have largely ceded most discussions about how to revive economic growth to Republicans. And unfortunately, while Democrats can be accused of indifference to important economic issues, Republicans actually harbor deep ideological opposition to the institutional reforms needed to revive U.S. manufacturing innovation.

One might expect the Republican Party to be a natural home and advocate for such a mission. The first item on the GOP platform is "rebuilding the economy and creating jobs." But any discussions about active economic development are deeply taboo in mainstream Republican thinking.

The dominant conservative belief is that industrial strategy means picking winners. In fairness, this is a justly discredited strategy. Picking winners means picking losers: privileging politically connected yet economically incompetent businesses or sectors. But there are other strategies besides this "vertical" type of industrial policy. Building missing institutions, such as innovation intermediaries, is not the same as this discredited approach. It is a "horizontal policy" that has benefits across companies and sectors, supporting the economy as a whole. Yet even this approach would be at odds with the market fundamentalism that is characteristic of much of the modern Republican Party's economic thinking.

Market fundamentalism does not acknowledge the role of the military and government in developing America's advanced technology and our most successful industries. It seems to believe that technology develops by itself, as if by magic. It also does not acknowledge that there may be a tension between what is good for an activist investor and what is good for the economy as a whole. Market fundamentalism has no opinion, aside from the market's, on whether corporate R&D should be more than "a hobby."

In both parties there are countervailing trends to these dominant themes. The handful of innovation intermediaries in the United States are products of the Clinton and Obama administrations. Trump was elected in part because of his manufacturing agenda and his promise to restore good blue-collar jobs. His campaign rhetoric offered a different approach from the market fundamentalism of mainstream Republicans. But when it came time to create actual policies, it was back to the Paul Ryan agenda, with tax policy as the principal lever for economic development.

This is a mistake. Improving U.S. applied innovation and creating the jobs that come with it will require much more than tax incentives. The success of manufacturing in Germany, Taiwan, and South Korea, among others, demonstrates that there is an entire set of policies beyond taxation necessary to foster growth through reindustrialization.

On a more optimistic note, state and city policymakers typically don't have the same ideological qualms about active economic development as Washington ideologues. On the contrary, local policymakers are often explicitly charged with finding ways to attract new businesses and good jobs—to find things that work. Thus states and cities, rather than the federal government, might be the best sites for experiments (and funding) aimed at fixing the U.S. weakness in applied R&D.

The Radicalism of Incremental Advances

America risks becoming a low-skill, low-wage nation. The country is filled with rage, but the rage is misdirected: this downward economic trajectory isn't being addressed by social justice activism or market fundamentalism. Sadly, an entire set of solutions related to restoring innovation in manufacturing seems ideologically off-limits in both parties.

But perhaps the biggest problem is that the problem itself remains largely unknown. It is simply inconceivable to most Americans that the United States is not the best in the world when it comes to applied research and innovation, or that the country lacks key institutions that could better support advanced manufacturing. These topics are almost never discussed in the media. Sophisticated political economists and regional planners may be aware of these issues, but mainstream macroeconomists are not, preferring instead to model general equilibrium dynamics.[18]

Building new institutions like innovation intermediaries is hard. Adapting models that have worked well in Germany or Japan or Korea to the United States is harder still. But it is no more difficult—and probably much easier—than correcting the abuses of "free trade" by mercantilist competitors, or taking on short-termism in financial markets—the other leading causes of U.S. economic deindustrialization.

America has faced technological challenges in the past and overcome them. The defense agency DARPA, for instance, was created in response to Sputnik. "DARPA explicitly reaches for transformational change instead of incremental advances," according to the agency, with the goal that the United States "would be the initiator and not the victim of strategic technological surprises."[19]

The United States should not abandon the advantages that DARPA and other institutions have secured in upstream, basic R&D. But now America needs the equivalent of a new DARPA—with an expanded, and not just a military, mission—to focus on the less glamorous world of "incremental advances" in process innovation. America needs to be the initiator, not the victim, of strategic technological surprises when it comes to actually making things.

This article originally appeared in AMERICAN AFFAIRS *Volume II, Number 2 (Summer 2018): 80–95.*

NOTES

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2 Adam Davidson, "Making It in America," *Atlantic*, January/February 2012.

3 For a discussion of the statistical controversies around U.S. manufacturing output, see David Adler, "The Real Challenge for U.S. Industry," *City Journal*, March 29, 2017.

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8 Henry Kressel. "Edison's Legacy: Industrial Laboratories and Innovation." *American Affairs* 1, no. 4 (Winter 2017): 115–29.

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[10] Peltz's comment has been reported widely. See for instance, Wendy Lea, "Peltz's Proxy Fight with P&G Misguided," *Cincinnati.com*, October 6, 2017.

[11] Lorsch is quoted in the article, Stephen Gandel, "How DuPont Went to War with Activist Investor Nelson Peltz," *Fortune*, May 11, 2015. Note that this article was written before DuPont lost the war.

[12] See also Susan Helper and Howard Wial, "Strengthening American Manufacturing: A New Federal Approach," Brookings Institution, September 27, 2010.

[13] "Productivity and Costs, Fourth Quarter and Annual Averages 2017, Revised," Department of Labor Bureau of Labor Statistics, March 7, 2018.

[14] Susan Christopherson and Jennifer Clark, *Remaking Regional Economies: Power, Labor, and Firm Strategies in the Knowledge Economy* (London: Routledge, 2007), 131–32.

[15] Willy C. Shih, "The U.S. Can't Manufacture the Kindle and That's a Problem." *Harvard Business Review*, October 13, 2009.

[16] This definition is from the National Academy of Sciences and nearly matches the textbook definition of "process innovation." For more about Fraunhofers and innovation intermediaries across the world, see National Research Council, *21st Century Manufacturing: The Role of the Manufacturing Extension Partnership Program* (Washington, D.C.: National Academies Press, 2013).

[17] Edmund Phelps, "America's Policy Thinking in the Age of Trump" (speech at the annual meeting of the American Economic Association, Philadelphia, January 2018).

[18] There is a growing literature in political science and economic geography focused on the links between innovation and production, and America's weakness in downstream R&D. See, for example, *Production in the Innovation Economy* (Cambridge: MIT Press, 2014); Dan Breznitz, *Innovation and the State: Political Choice and Strategies for Growth in Israel, Taiwan, and Ireland* (New Haven: Yale University Press, 2007); and publications from the American Association of Economic Geography Specialty Group, and the Industries Studies Association.

[19] "About DARPA," Defense Advanced Research Projects Agency.